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Trade, Foreign Investment and the Environment: The Brazilian Experience

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The Working Group on Development and Environment in the Americas, founded in 2004, brings together economic researchers from several countries in the Americas who have carried out empirical studies of the social and environmental impacts of economic liberalization. The Working Group's goal is to contribute empirical research and policy analysis to the ongoing policy debates on national economic development strategies and international trade. The Working Group held its inaugural meeting in Brasilia, March 29-30, 2004. This paper is one of eight written for the Brasilia meetings. They are the basis for "**Globalization and the Environment: Lessons from the Americas,"** a policy report published by the Heinrich Böll Foundation in July 2004.

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Introduction

The basis of Brazilian trade policies in the last decade has consistently been greater openness, both in commercial and financial terms. Some of the arguments in favor of these market-oriented policy reforms state that economic liberalization reduces static inefficiencies arising from resource misallocation and that economic liberalization enhances learning, technological change, and economic growth.[1] The objective is to deepen modernization and competitiveness of the production sectors in order to increase their participation in global markets.

Nevertheless, there are strong criticisms of the way these policies are being implemented in Brazil. The most conventional arguments are related to concerns about deindustrialization and a return to the stage of dependence on natural resource-based activities. The reversal of the trade balance and massive unemployment in the industrial sector observed in the mid-nineties are usually pointed to as negative consequences of the accelerated trade liberalization program. This issue is complex and is already receiving considerable attention by researchers.

But another crucial point has not yet penetrated the trade liberalization discussions in Brazil: the environmental consequences associated with freer trade. The theoretical debate over trade and environment is not new,[2] but its importance has increased substantially with the trade liberalization processes that have been taking place around the world. The hypotheses about the trade and environment link can be divided in two groups. On one side, there exists the possibility that countries with lower environmental standards would develop a comparative advantage in dirty industries. This is associated with the so-called pollution haven hypothesis.[3] From another perspective, there exists the possibility that imposing environmental controls and regulation in order to avoid the pollution intensive specialization, a country would create additional costs and thus lose competitiveness in world markets.[4]

This is the main focus of this research: if economic growth recovers with a strong component of export-led activities (as expected by policy experts in the government and in the international agencies), what are the long-term consequences of this strategy? Is expanding Brazilian exports (and production as a whole) compatible with the prevention of worsening pollution problems? On the other hand, what would be the economic costs of improving pollution control and other mitigation measures?

Therefore, this study will be divided in two parts. The first one will deal with the consequences of rising industrial output (particularly those associated with exports) for urban pollution. This section will examine the impact of greater openness to trade – proxied here by industrial exports – on the level of urban pollution. The methodology will be based on the use of input-output modeling techniques, whereby pollution emission coefficients are linked with industrial activities. The aim is to estimate the total amount of emissions required to obtain a specified industrial export volume (exogenously determined).

The second part of the study will emphasize the consequences of pollution control/mitigation costs for export competitiveness. This section will be an extension of the previous one. Given the impact of industrial exports on urban pollution, what would be the impact on external competitiveness of the adoption of pollution controls? The analyses will make use of a combination of (estimated) mitigation costs and price elasticities of the demand for industrial exports, also considering chain effects through input-output modeling. There will be, additionally, an effort to estimate employment impacts of pollution abatement expenditures.

2 Trade and the Environment in Brazil: A Historical Perspective

The deep distrust of the environmentalist movement about the consequences of increasing openness is strongly related to the role played thus far by foreign markets in Brazilian history. The 500 years since the arrival of the Portuguese in Brazil (22 April 1500) has been dominated by environmental degradation caused directly or indirectly by trade relations. The early occupation of the colony was already determined by trade, and even the name of the country was after a commodity: the once upon abundant pau-*brasil* tree (*Caesalpinia echinata*), which was highly demanded in European markets as a source of red tincture used to color fabrics. The depletion was so accelerated that, in less than 60 years after discovery, the best reserves could only be found 20 km away of the shore (Bueno, 1998). In the first century after discovery, an estimated 2 million trees were cut down and shipped to Europe, and by 1605, growing scarcity led the Portuguese Crown to ask for action against unplanned logging, and forest rangers were distributed along the Brazilian coast (Bueno, 1998). Not surprisingly, the *pau-brasil* tree became almost extinct in Brazilian native forests.

The other economic cycles during colonial times were also dominated by the overexploitation of natural resources in order to provide goods to be shipped abroad – the main purpose of the colony was to profit via trading commodities based on the abundant natural resources (Furtado 1959). The sugarcane cycle in the Northeast and Southeast, which took place in the first two centuries of Portuguese settlement, was the first wave of massive destruction of the Atlantic rainforest (*Mata Atlântica*). There were two reasons why forests were endangered: demand for agricultural land and for timber and fuelwood. The technological pattern used by the Portuguese (and the Dutch, during their brief occupation of the sugarcane plantations in the Northeast) in the processing of sugar was not very different from the one that resulted in the total depletion of native forests in the Madeira island.[5]

In the XVII and XVIII centuries, the gold cycle in Minas Gerais and other interior parts of the country resulted not only in the quick exhaustion of reserves (which lasted less than two centuries), but also in considerable damage to the environment caused by mining techniques. Changing the natural courses of rivers became a common practice to search for gold, and an even more harmful technique was to deviate the river flow against its margins, “washing” the embankments to reveal the precious ore (Dean 1996). Cattle raising was not directly connected to trade relations with Europe, but was indirectly encouraged by them, as the rising demand for meat in the mining areas established cattle migration routes and increased the pressure for overgrazing, which has seriously damaged natural pasture areas, particularly in the interior of the Northeast.

Another crucial element in the economic formation of Brazil was slavery. The development of international trade routes, followed by the industrial revolution, cannot be dissociated from the triangular trade between Europe, Africa and the Americas, even though this issue is usually neglected in the current debate, which tends to forget this tragic consequence of the development of international trade routes in the past. Brazil was the place which received the highest number of Africans, and almost four centuries of slavery has brought scars that are yet to be healed, including the deepest social inequality in the Western world. Slaves were an essential part of the sugarcane production, the mining of gold and other precious ores, and almost any other commodities produced for foreign markets (such as tobacco and cotton).

Independence did not change this pattern, and coffee plantations were a main driver of the Imperial economy. This new commodity was again destined for foreign markets (this time without the interference of the metropolis, with the increasing importance of the British Empire and the United States as trade partners) and the rising exports were accomplished through the massive destruction of the Mata Atlântica. The State of Rio de Janeiro was the first one to suffer the invasion of coffee plantations: Dean (1996) estimated that around 18% of the total area of the state was cleared for coffee plantations, employing around 140,000 slaves. However, the unsustainable practices led to the fast decline of production, up to its complete eradication. At present, most of these areas in the state of Rio de Janeiro are used for cattle raising with very low productivity.

Slavery was abolished only in 1888 and, not by coincidence, one year after the Republic was proclaimed. However, the expansion of coffee exports at the expense of clearing native rainforests was not disturbed by this change. Using migrants from Southern Europe (mainly Italians), coffee remained the main economic factor in Brazil until the world recession during the 1930s. The more appropriate soils in the State of São Paulo (*terra roxa*) and less erosive practices have resulted in more permanent cultivation, but the clearing of forest areas remained the main means of output expansion. The wave of forest clearing has also migrated to the states of Paraná and (Southern) Minas Gerais. The final balance of this and other forest-consuming activities (such as charcoal production in Minas Gerais, and pulp and paper production in Paraná and Santa Catarina) is the reduction of the Mata Atlântica to less than 7% of its original area.

One exception of this trend was the natural rubber boom in the Amazon in the late 19th century and early 20th century. This was an important economic cycle directed to foreign markets that was based in extractive practices with little harm to the environment (since the trees are not destroyed during the latex extraction). Unfortunately, this mostly sustainable activity could not face the competition of rubber tree plantations in Southeastern Asia (which have had important deforestation consequences in these regions), and the decline in production has resulted in the paradoxical situation of Brazil currently being a net importer of natural rubber.

The 1930s crisis represented an important change in policy making in Brazil. So far, all major economic relations were oriented towards foreign markets, and there was little integration of activities aiming at domestic markets. Even the spatial distribution of the country was shaped according to the proximity to export ports. The economic dependence on the exports of a natural commodity resulted in a cycle of crisis, caused by falling prices in external markets when supply increased over demand, which usually happened after a period of boom when prices had previously gone up. Therefore, in the 1940s and, especially in the 1950s, a new strategy of growth was adopted, based on the idea that Brazil (as other developing countries) would have to increase its participation in the global markets as a supplier of industrialized goods. Otherwise it would become permanently relegated to a second-class position. This strategy was heavily influenced by the so-called Latin American Structuralist school, following the pioneering studies of Raúl Prebisch, which has shown that an outward-oriented economy based on primary goods (and, therefore, not incorporating the benefits of technical progress) would never develop to its full potential.[6] A new pattern of development was required, in which industrialization would become the main objective.

The golden age of industrialization in Brazil (1950s, 1960s and 1970s) resulted in rapid economic growth and structural changes in the productive structure. Nevertheless, the social and environmental consequences of this process were far from desirable. There is already a considerable number of studies on social exclusion in the Brazilian industrialization process, but the consequences for the environment are yet to be researched in detail. The expansion of industrial activities was not followed by the establishment of pollution control authorities: the first environmental agency (FEEMA, in the State of Rio de Janeiro) was created only in 1977, when the industrialization process was already losing its momentum and the rates of investment and output growth rates were declining from their historical averages. Indeed, the first effective national environmental law was created only in 1981. The pollution consequences of this lack of standards and mitigation procedures were dramatic, as exemplified by the tragedy of Cubatão industrial area (in the state of São Paulo).[7] Therefore, the shift towards more inward-oriented development did not result in improvements in the environmental area.

One common misunderstanding is the belief that, during the import-substitution process, export-oriented policies were not important. In fact, exports played a major role in financing the industrialization process, which was intensive in imports, particularly machinery and intermediate inputs. For instance, the II National Development Program (1975-79), a crucial stage in completing the industrial structure, included among its main targets the expansion of export capacity in intermediate goods, such as metallurgy, petrochemicals, and pulp and paper. Providing fiscal and credit incentives to these sectors, characterized by their high consumption intensity of energy and other natural resources, has created a pattern of high emission activities that has considerably affected the Brazilian industrial export capacity. The environmental consequences of this shift in the export structure towards more energy (and pollution) intensive goods will be discussed in this study.

An important shift towards trade liberalization and privatization has occurred in the 1990s. Import barriers were lifted, there were legal changes in order to ease foreign investment, and the process of economic integration within the South American free trade agreement (Mercosul) gained speed. The impact of these measures has been concentrated mainly in deregulation and the increase of imports, particularly as a result of the overvaluation of the exchange rate after the Real economic plan (1994).

Measured in terms of proportion to the GDP, there was no significant improvement in the export level, or the sum of exports and imports. But other changes can be more easily identified: industrial output increased, but industrial employment fell. The environmental changes associated with these transformations are analyzed in the following sections.

In summary, the environmentalist's position is strongly influenced by the past and present consequences of international trade in Brazilian history, which has plenty of examples of how natural resource depletion and degradation were a hidden cost of increasing exports. Therefore, they tend to be very skeptical about the argument that the future is not necessarily a reproduction of the past and that, under certain ideal conditions (full implementation of property rights in order to resolve market failures, and the correction of public policies that encourage the overexploitation of natural resources), improvements in trade relations will not represent an additional threat to the environment. Indeed, they tend to consider that implementation of these policy reforms is either unrealistic under the social and political structure of Brazil, or, even worse, they would result in further harm to the environment, since the economic groups that tend to benefit from trade expansion are not concerned with the social and environmental damages caused by it. Nevertheless, their refusal to accept both the outward-looking model imposed by globalization and the inward-looking economic growth experienced in the industrialization period (also harmful to the environment) has not yet been accompanied by feasible policy suggestions.

3 The Environmental Debate in the Economic Literature

If the environmentalist movement (and NGOs in general) have shown deep concern about the consequences of trade for the environment because of ideological positions (mostly motivated by historical events), part of the economic literature on the subject tends to present the opposite vision. The most important arguments presented by those who defend the positive environmental aspects of international trade are that higher competition would close down companies operating with old and inefficient equipment. These are the companies with higher probability of being environmentally harmful, either because of old machinery/technology or wastefulness in their production processes. A more competitive atmosphere would force them to adopt modern ways of production, which tend to be more efficient in all aspects, including those relating to the environment (in terms of emission avoidance and raw materials savings).

Eliminating subsidies or other incentives for energy-intensive sectors are an incentive to reduce energy consumption and, therefore, emissions and pollution. These sectors tend also to be capital intensive, and according to the theory of comparative advantages, free trade policies would favor a shift in developing countries towards labor-intensive activities, which tend to be less polluting.

The reduction of trade barriers would favor the imports of modern, state-of-the-art equipment. Since this machinery is developed to follow the tough environmental standards of developed countries, the acquisition of this equipment results in an overall improvement of the environmental performance of the importing country.

Consumers in developed countries are showing growing concern about the environmental standards of products they buy. This is forcing the adoption of environmentally friendly production patterns, certified by green labels, for those willing to export to these markets. Because of the demonstration effect, this behavior also ends up being adopted by producers aiming at domestic markets, and local consumers become more aware of the environmental implications of the production and consumption of the products they buy.

To understand the differences between those who object to trade and those who do not, it is crucial to bear in mind that most of these analytical studies are not based on historical analysis, but rather are deeply rooted in theoretical arguments derived from idealized models of reality (which, again, are strongly related to ideological positions). The recent document issued by the World Trade Organization (WTO 2000) is a good example of the belief that, under "ideal" circumstances, promoting free market is always the best policy:

"In the best of all worlds, governments would use proper environmental policies to 'internalize' the full environmental costs of production and consumption – the 'Polluter Pays Principle'. . . . In this idealized world, trade liberalization would unambiguously raise welfare" (WTO 2000, p.2)

Hence, the "conclusion" of this argument is simply a consequence of the fact that problems are eliminated by construction of any idealized world according to the beliefs of whatever ideology – including the one behind the free market. The "ideal world" is considered to be perfect exactly because it is the best application of that set of beliefs.[8] Nevertheless, this kind of argument is repeatedly used by governments and multilateral development agencies in their justification to deepen reforms towards more openness (for a critical analysis of the environmental consequences of adjustment policies, see Young 1997). Once problems are identified with the implementation of reform policies, it is usually considered not a fault of the policy itself but a "failure" of the real economy, in the sense that it does not behave according to the "perfect" world proposed by theory. The answer is that even more reforms are needed in a way to turn the real world "more perfect" – i.e., closer to the idealized theoretical model.

Nevertheless, once more realistic assumptions are considered, even neoclassical theoretical models present results showing that improving trade relations may result in damages to the environment. Three counter-arguments are commonly used to justify a change in the current regulatory framework concerning international trade that disallowed restrictions justified by environmental factors (WTO 2000):

1. The legal argument: the existing rules provide legal cover for foreign countries to challenge domestic environmental policies that interfere with their trading rights.

2. The political economy argument: the competitive pressure from the world market sometimes makes it impossible to forge the necessary political support at home to upgrade environmental standards.

3. The market failure argument: in the existing institutional conditions of developing countries, international trade may magnify the effects of poor environmental policies in the world (increasing the tendencies of overexploitation of natural resources). Or, in more general terms, that economic growth driven by trade may speed up the process of environmental degradation unless environmental safeguards are put in place.

The basic assumption of these arguments is that environmental standards are weaker in developing countries, stimulating the migration of pollution-intensive industries to such countries (for a review of these arguments, see Leonard, 1988, and Weil *et al*., 1990). Empirical evidence shows that polluting industries have in fact expanded faster in developing countries than the average rate for all industries (Lucas *et al*., 1992; Low and Yeats, 1992). However, the evidence is not clear about the existence of a migration process of dirtier industries from developed countries. Using trade and investment figures for US-based industries, Leonard (1988) concludes that, taken in the aggregate, the years immediately following the emergence of stringent environmental regulations in the United States did not witness widespread reallocation of pollution-intensive industries to countries with drastically lower regulatory requirements. Pollution abatement and control expenditures seem not to have significant effects on competitiveness in most industries, since they are small in comparison with total costs. Other reasons can be listed (Low, 1992), such as the fear of liability in the event of an accident; the reputation damages in the originating countries if it happens; the costs of 'unbundling' technology; potential claims of environmentally concerned consumers in export markets; expectations of more stringent local environmental standards in the future; and the relatively high costs of retrofitting aging capital equipment instead of starting up with 'top of the line' equipment. It has been observed empirically that open developing economies became less pollution intensive than closed economies in the 1970s and 1980s (Lucas *et al*., 1992; Birdsall and Wheeler, 1992).

This lack of a definitive answer to these opposing arguments is consistent with the results of recent surveys of theoretical models dealing with the issue (Ulph 1998):

> The literature has been timely in that the issue (the link between environmental policy and international trade) has been one of considerable public debate, and the literature has been well placed to address some of the issues raised by that debate, since the literature has focused on imperfect competition and the potential scope for governments to manipulate environmental policy for strategic reasons. I have shown that this recent analysis is capable of providing starkly different predictions of environmental policy under liberalized trade regimes from those derived from the traditional literature, but there is a severe problem of non-robustness of results. This is especially problematic when it comes to trying to draw policy conclusions from this new literature, although the analysis does not support some of the policy prescription discussed in popular debates (Ulph 1998, p.237-238).

The need for empirical findings is common ground in all studies which reject *a priori* statements such as “trade is good” or “trade is bad” for the environment – there is a strong need to improve our understanding of these links in the real economy. This is main the objective of the following sections: to provide a systematic empirical analysis of the link between international trade (more precisely, industrial exports) and the environment in recent decades in Brazil, in order to contribute to policymaking in the future.

The overall conclusion is that both sides of the debate are partially correct, in the sense they have considered only part of the whole process: trade reforms may, at the same time, improve and worsen environmental conditions. The main message for public policymaking is, therefore, that neither blocking trade relations nor *laissez-faire* policies are appropriate for improving environmental conditions in developing countries (or at least in Brazil). Trade is an important source of effective demand and employment generation, but there are important failures to be considered and corrected. The tendency of specialization in resource-intensive activities, empirically observed in Latin America for a long time (and the basis of the structuralist approach), results in higher than average emission coefficients in the export sector. On the other hand, the higher pressure for environmental standards imposed by some OECD consumer markets, plus a more environmentally friendly behavior by companies of global insertion, leads to a counter-effect of disseminating environmental innovations in the productive structure.

The question is how to reduce the first trend and accelerate the second one. The encouragement and diffusion of environmental innovations and a wider comprehension of the social dimensions of the pollution problem, coupled with the elimination of policy failures that encourage the establishment of pollution-intensive industries (an issue particularly important in the recent "fiscal war" among Brazilian states, which offer all kinds of subsidies and incentives to attract investments) are among the policy options to be pursued.

4 Industrial Emission Model

Input-output model

The objective of the input-output model is to describe the interdependence of the economy, given the current levels of production and consumption. Assuming that all the (*n*) sectors of an economy keep a constant share in the market of each product, and that the production processes of all these sectors are technologically interdependent and characterized by a linear relation between the amount of inputs required and the final output of each sector, it is possible to obtain a system containing *n* equations relating the output of every sector to the output of all other sectors. The model also considers an autonomous sector (final demand) which is determined exogenously to the model. The sales of each sector should be equal to autonomous consumption (related to the categories of final demand) plus the amount of production destined to the intermediate consumption of all the other sectors (Dorfman, 1954).

In formal terms:

$$x_i = \sum_{i=1}^{n} x_{ij} + C_i + I + G_i + E_i - M_i \qquad (1)$$

where x_{ij} is the amount of output from sector i demanded as intermediate consumption to sector j, and C_i, I_i, G_i, E_i, M_i and x_i are, respectively, the private consumption, investment, public administration consumption, exports, imports, and domestic production of sector i (Prado, 1981).

The basic assumption is that the intermediate consumption is a fixed proportion of the total output of each product:

$$x_i = \sum_{j=1}^{n} a_{ij} \cdot x_j + d_i \qquad (2)$$

where a_{ij} is the technical coefficient determining the amount of product of sector i required for the production of one unit of product in sector j, and d_i is the amount of final demand for products from sector i ($d_i = C_i + I_i + G_i + E_i - M_i$). In matrix terms, this is expressed by:

$$x = Ax + d \qquad (3)$$

Where x is a nx1 vector with the total product of each sector, d is a nx1 vector with sector final demand, and A is a nxn matrix with the technical coefficients of production.

Since the final demand is exogenously determined, the intermediate consumption can be obtained by the following equation:

$$x = (I - A)^{-1} d \qquad (4)$$

Where $(I - A)^{-1}$ is the nxn matrix containing the input-output coefficients for the relations between sectors.

The same formula is valid for calculating the direct and indirect effects of exports or any other component of the final demand, instead of its aggregate:

$$x_f = (I - A)^{-1} d_f \qquad (5)$$

Where x_f is the nx1 vector containing the total production per sector necessary to obtain the nx1 vector of the f-category of final demand (d_f).

Therefore, the input-output model allows the determination of the level of economic activity in each productive sector as a function of the final demand for each product.

Introducing Emission Coefficients

The use of extended input-output tables to estimate emissions and other discharges of residuals has become an important instrument to assess environmental problems at the macroeconomic level (for a review, see Førsund, 1985; the methodology adopted in this section is based on Pedersen, 1993). The most common procedure is to assume that emissions are linearly related to the gross output of each sector, in a way that each industry generates residuals in fixed proportions to the sector output. The emission coefficient of pollutant h by sector i (ef_{hi}) can be obtained by dividing the total emission of a sector (em_i) by the total output of the same sector (x_i):

$$ef_{hi} = \frac{em_{hi}}{x_i} \qquad (6)$$

Given this assumption, it is possible to obtain the total emission caused by the f-category of final demand through the use of emission coefficients for each sector. In formal terms, this is expressed by:

$$z_{hf} = diag(ef_h) \cdot x_f = diag(ef_h) \cdot (I - A)^{-1} d_f \qquad (7)$$

Where z_{hf} is the nx1 vector containing the total emission of pollutant h per sector associated to the f-category of final demand, and $diag(ef_h)$ is the nxn matrix containing in its principal diagonal the emission factors of pollutant h for each sector, and zeroes elsewhere (Pedersen, 1993).

Measuring the Composition Effect

It is possible to disaggregate the changes in the emission pattern of the industry in three different effects:

a) Scale effect: refers to changes in emissions caused by the changes in the overall output level caused by the expansion (or retraction) of activities associated with more exposure to the world economy.

b) Composition effect: refers changes in emissions caused by the industrial restructuring that takes place because of that higher exposure to the world market. In other words, the composition effect considers the change in emissions because some sectors have their share increased in the economy's total output, while others have it reduced.

c) Technology (or technique) effect: refers to changes in emissions caused by innovations introduced because of the openness of the economy.

The input-output model allows the identification of the scale and composition effects, but the technology effect cannot be captured because of the use of fixed emission coefficients. In analytical terms, the argument of specialization in "dirty" activities is usually associated with the composition effect. The composition effect occurs when the proportion of emissions directly or indirectly associated with exports in relation to the total emissions exceeds the ratio between the value of production associated with exports and the total value of production of the economy. In formal terms:

$$\frac{[1]_{1\times n}(I - A)^{-1} d_x}{[1]_{1\times n}(I - A)^{-1} d} < \frac{[1]_{1\times n}\, diag(e_h).(I - A)^{-1} d_x}{[1]_{1\times n}\, diag(e_h).(I - A)^{-1} d} \qquad (8)$$

where:

$[1]_{1xn}$ is a line-vector with the number 1 in every cell; n is the number of sectors in the economy;

$(I-A)^{-1}$ is the nxn Leontief inverse matrix; $diag(ef_h)$ is the nxn diagonal matrix containing the emission factors of pollutant h for each sector, and zeroes elsewhere (obtained in equation); d_x is the vector containing the exports of each of the n sectors; d is the vector containing the final demand of each of the n sectors.

The left side of expression (8) represents the proportion of the output directly and indirectly required by the exports compared to the total output, and the right side represents the emissions of pollutant h directly or indirectly caused by exports divided by the total emissions of this pollutant. If the right side is bigger than the left side, the composition of goods destined to foreign markets is more intensive in emissions of pollutant h than the average of the economy.

5 Application to Brazil

This section describes the procedures used to estimate equation (7) for the Brazilian economy, combining the input-output tables (42x42 activities) prepared by the Brazilian Institute of Geography and Statistics (IBGE) and four different sets of emission coefficients, for local and global pollutants. The objective is to empirically test the hypothesis of a composition effect in the sense that Brazilian industrial exports are specialized in relatively dirty activities if compared to the production destined for the domestic market.

The IPEA Emission Coefficients (Local Pollutants)

The first set of emission coefficients (for local pollutants) was calculated using the results from empirical studies carried out by the Environmental Economics Research Division at IPEA (Serôa da Motta *et al.*, 1993; Mendes, 1994; Serôa da Motta, 1993a, 1993b, 1996). These studies estimated the effectiveness of abatement policy and the status of current water and air industrial pollution in Brazil, based on indicators of water and air quality for 13 states where systematic monitoring is undertaken.[9] This database was built using pollution emission and abatement estimates for the year 1988 according to a World Bank funded project denominated PRONACOP (Brazilian National Program of Pollution Control), covering 12 states, plus similar information for the state of São Paulo for the year 1991, using data from the state's environmental agency (CETESB). The parameters considered were biochemical oxygen demand (BOD) and heavy metals for water pollution, and particulate matter, sulfur dioxide (SO_2), nitrogen oxides (NO_x), and hydrocarbons (HC) for air pollution.

The estimates of potential emissions were obtained by multiplying the potential output of every industrial establishment registered at the respective state environmental agency by emission parameters obtained from the technical literature (taken mostly from the World Health Organization). These potential pollution emissions were considered as a measure of the level of pollutant emitted by the industrial establishment without any treatment.

The second stage was to estimate the level of remaining emissions (potential emissions minus abatement capacity), considered a better proxy for the effective level of industrial emissions. The pollution treatment capacity of every industrial unit was calculated according to the potential for emission treatment at the source points (i.e. every industrial establishment registered in the database). The indicators of (remaining) emissions were then divided by the value added of the respective industrial sectors, at the state level, in order to produce the emission intensity coefficients (for more details, see Mendes 1994).[10] Tables 1 and 2 present the average values for the 13 states.

Table 1: Water pollution: potential and remaining emission intensity coefficients, by industrial sector (g/US$ of value added), IPEA

Industrial sector	Biochem. Oxygen Demand		Heavy Metals	
	Potential	***Remaining***	***Potential***	***Remaining***
Metallurgy	**1.12**	**0.04**	**1.73**	**0.85**
Mechanical	**0.73**	**0.60**	**0.16**	**0.07**
Transport equipment	**0.49**	**0.18**	**0.13**	**0.05**
Wood products	**19.83**	**8.82**	**0.00**	**0.00**
Paper & cellulose	**37.35**	**12.91**	**0.00**	**0.00**
Chemicals	**86.85**	**16.15**	**0.03**	**0.03**
Drugs & medicine	**2.25**	**1.47**	**0.00**	**0.00**
Cosmetics & soap	**7.02**	**4.58**	**0.00**	**0.00**
Textiles	**7.11**	**4.40**	**0.00**	**0.00**
Leather & footwear	**45.36**	**21.69**	**1.84**	**0.76**
Food products	**27.96**	**11.31**	**0.00**	**0.00**
Beverages	**105.11**	**40.98**	**0.00**	**0.00**
Source: Mendes (1994)				

Table 2: Air pollution: potential and remaining emission intensity coefficients, by industrial sector (g/US$ of value added), IPEA

	Partic. matter		SO_2		NO_X		HC	
Sectors	***Potential***	***Remaining***	***Potential***	***Remaining***	***Potential***	***Remaining***	***Potential***	***Remaining***
Non-metallic minerals	**689.1**	**261.4**	**51.2**	**51.0**	**10.9**	**10.9**	**0.2**	**0.2**
Metallurgy	**247.0**	**111.4**	**50.7**	**50.7**	**17.2**	**17.2**	**6.2**	**6.2**
Mechanics	**5.8**	**1.1**	**1.3**	**1.3**	**0.1**	**0.1**	**2.0**	**2.0**
Electric materials	**0.4**	**0.1**	**0.2**	**0.2**	**0.0**	**0.0**	**2.2**	**1.6**
Transport equip.	**0.4**	**0.1**	**0.2**	**0.1**	**0.0**	**0.0**	**0.6**	**0.5**
Wood products	**42.2**	**42.1**	**2.5**	**2.5**	**9.7**	**9.7**	**2.9**	**2.9**

Paper & cellulose	**133.8**	**28.2**	**16.0**	**15.8**	**32.5**	**32.5**	**0.7**	**0.7**
Rubber products	**0.4**	**0.4**	**3.3**	**3.3**	**0.5**	**0.5**	**0.1**	**0.1**
Chemicals	**41.4**	**18.3**	**61.4**	**59.9**	**45.7**	**45.6**	**38.8**	**18.4**
Drugs & medicine	**0.4**	**0.4**	**2.0**	**1.9**	**5.5**	**5.5**	**0.1**	**0.1**
Domestics & soap	**8.8**	**4.5**	**32.3**	**32.3**	**2.9**	**2.9**	**0.1**	**0.1**
Textiles	**26.4**	**24.3**	**13.8**	**13.4**	**11.2**	**11.2**	**0.4**	**0.3**
Leather & footwear	**1.0**	**0.9**	**5.5**	**5.5**	**0.7**	**0.7**	**0.7**	**0.7**
Food products	**27.5**	**21.8**	**72.5**	**72.5**	**8.8**	**8.8**	**0.2**	**0.2**
Beverages	**68.1**	**58.2**	**35.7**	**35.7**	**17.4**	**17.4**	**0.4**	**0.4**
Source: Serôa da Motta et al. (1993)								

Table 3 presents the results of associating the above coefficients to the input-output tables, as stated in equation (7), in order to obtain (remaining) emission coefficients for each category of final demand.

Table 3: Pollution intensity per unit of output (kg/US$ Millions)

Parameter/year	Investment*	Exports	Public Consumption	Private Consumption	Total
BOD					
1985	**569**	**1420**	**361**	**1298**	**1043**
1990	**436**	**1292**	**277**	**1243**	**936**
1995	**453**	**1370**	**288**	**1116**	**861**
Metals (water)					
1985	**31**	**44**	**3**	**14**	**21**
1990	**24**	**50**	**3**	**13**	**17**
1995	**24**	**47**	**2**	**10**	**15**
Particulates (air)					
1985	**9364**	**7760**	**1296**	**4118**	**5553**
1990	**9390**	**8497**	**1041**	**3938**	**5035**

1995	**8232**	**8549**	**1034**	**3398**	**4441**
SO_2					
1985	**4146**	**6957**	**1134**	**4268**	**4278**
1990	**3520**	**6441**	**884**	**3983**	**3652**
1995	**3356**	**6442**	**855**	**3528**	**3298**
NO_X					
1985	**1878**	**3243**	**860**	**2011**	**2029**
1990	**1613**	**2969**	**646**	**1918**	**1763**
1995	**1574**	**3029**	**666**	**1672**	**1603**
HC					
1985	**674**	**1105**	**188**	**585**	**636**
1990	**575**	**974**	**148**	**554**	**537**
1995	**566**	**880**	**138**	**430**	**448**
CO					
1985	**40265**	**51294**	**4525**	**14781**	**24792**
1990	**32104**	**58715**	**3519**	**13318**	**20030**
1995	**31445**	**55460**	**3113**	**10899**	**17855**
* *Investment includes changes in stocks*					

For all pollutants analyzed, the amount of emissions required to produce one unit of export-related output exceeds the average of the economy. Indeed, the intensity of pollution is higher in export-related activities than in any other group for all but one parameter (particulates, in which exports are the second highest). In other words, exports are more pollution-intensive than the average of the economy for almost every pollutant considered.

In sector terms, it is clear that a few sectors account for most industrial water and air pollution. These 'dirty' industries are usually related directly or indirectly to export-oriented activities, such as metallurgy (input for the automobile industry and other industrial export goods), paper and cellulose, and footwear (leather products). The most important polluting industries are: chemicals, food products, and paper and cellulose for BOD; metallurgy for heavy metals; non-metallic minerals and metallurgy for particulate matter; chemicals, metallurgy and non-metallic minerals for SO_2; chemicals, metallurgy, paper and cellulose, and food products for NO_X; and chemicals for HC.

Table 4: Pollution intensity per unit of output (kg/US$ Millions)

Parameter/year	Investment*	Exports	Public Consumption	Private Consumption	Total
BOD					
1985	**569**	**1420**	**361**	**1298**	**1043**
1990	**436**	**1292**	**277**	**1243**	**936**
1995	**453**	**1370**	**288**	**1116**	**861**
Metals (water)					
1985	**31**	**44**	**3**	**14**	**21**
1990	**24**	**50**	**3**	**13**	**17**
1995	**24**	**47**	**2**	**10**	**15**
Particulates (air)					
1985	**9364**	**7760**	**1296**	**4118**	**5553**
1990	**9390**	**8497**	**1041**	**3938**	**5035**
1995	**8232**	**8549**	**1034**	**3398**	**4441**
SO_2					
1985	**4146**	**6957**	**1134**	**4268**	**4278**
1990	**3520**	**6441**	**884**	**3983**	**3652**
1995	**3356**	**6442**	**855**	**3528**	**3298**
NO_X					
1985	**1878**	**3243**	**860**	**2011**	**2029**
1990	**1613**	**2969**	**646**	**1918**	**1763**
1995	**1574**	**3029**	**666**	**1672**	**1603**
HC					
1985	**674**	**1105**	**188**	**585**	**636**
1990	**575**	**974**	**148**	**554**	**537**
1995	**566**	**880**	**138**	**430**	**448**

CO					
1985	**40265**	**51294**	**4525**	**14781**	**24792**
1990	**32104**	**58715**	**3519**	**13318**	**20030**
1995	**31445**	**55460**	**3113**	**10899**	**17855**
* *Investment includes changes in stocks*					

If the (fixed) emission coefficients estimated by IPEA with data for the Brazilian industry (for the 1988/91 period) are applied to a time series up to 1995, there is a clear trend of declining average intensity of emissions per unit of output for all parameters considered. This indicates that the composition of the Brazilian industrial output has changed towards less (potentially) polluting activities. However, the emissions intensity in the export complex for metals, particulates and CO would have increased, showing an increase in the dependence of Brazilian industrial exports in (potentially) dirty activities.

Note that it is important to bear in mind the many limitations involved in this approach. Among them, three are particularly important. First, the emission estimates were not obtained directly from observations of the quality of water and air at the emission points but indirectly, from the specifications of the industrial plants surveyed. However, the environmental impact of a specific pollutant is affected by many other variables that were not considered in the exercise.[11] Second, a linear relationship is assumed between value added and the level of emissions – it is possible that this relationship is far more complex. Third, only the establishments that were registered with the environmental agencies could be considered. It is possible that the total amounts of emission were underestimated. This point would be important in the case of sectors where a very large number of only marginally polluting establishments are responsible for a considerable amount of the total emissions.

IPPS Emission Coefficients (Local Pollutants)

Production and emissions data from 200,000 factories in the United States (1987) were merged to obtain estimates of sector pollution intensity (pollution per unit of activity), and used by the World Bank as the basis for the Industrial Pollution Projection System (IPPS). Although the estimates based on the IPPS are not actual emissions, they can be useful as a guideline in order to rank industrial sectors in terms of their potential emissions.[12]

The IPPS index expresses the pollutant output intensity for six types of air pollutants (SO_2, NO_2, CO, VOC, PM10, TP), three types of water pollution (BOD, TSS and metal) and metals disposed in landfills.[13] Pollution intensity is expressed as pollutant output divided by total manufacturing. The total manufacturing activity can me measured by many variables, but the main choice is between the value and the output quantity. Only industrial activities are covered.

The IPPS provides emission coefficients based on the value of production (shipment value), value added, or employment. Since the input-output coefficients usually refer to the first of these categories, the coefficients used in this exercise refer to emissions divided by the value of production. Additionally, it is very important to mention that the EPA data used to calculate the

IPPS coefficients only cover facilities releasing pollutants over a threshold level of emissions. Consequently, pollution intensities based on these data may be biased. In this study, it was decided that the *lower bound* coefficients were more appropriate to estimate the Brazilian industry environmental performance. These coefficients assume the hypothesis that non-reporting facilities had no emissions (i.e., they were assigned with zero emissions). Hence, there is an underestimation bias in the calculation of emissions using these coefficients.[14]

The use of IPPS coefficients in the estimate of Brazilian industrial emissions also assumes that there were no significant technical differences between the production sectors in both countries (at least in terms of average emissions per unit of output). Therefore, since the effective degree of emission treatment in Brazil is unknown, it is very likely that errors result from the application of the IPPS coefficients. Moreover, since the denominator is expressed in monetary terms (value of production), an additional assumption is that the relative price structures in both countries are the same, which is very unlikely to occur in real terms. Finally, there is the problem of translating the classification of IPPS coefficients to the IBGE input-output classification. The aggregation level of IPPS is the International Standard Industrial Classification (ISIC) level 4, more detailed than the classification level 80 adopted in the input-output tables of IBGE. This also includes the problem of non-equivalence in the translation of classifications, such as the lack of IPPS emission coefficients for the coffee industry (for which emission coefficients were considered to be zero) and alcohol processing (aggregated to sugar processing in the IPPS, but considered by IBGE together with chemical elements).

In summary, the results obtained through these coefficients (tables 5 to 13), must be examined with extreme caution because of the methodological problems described above and, as already warned, they can only be considered to be *potential* indicators of actual emissions (which are, in fact, unknown).

Table 5: Emission intensities: BOD, kg/US$ millions (1987), IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	**310**	**130**	**195**	**252**
1990	**315**	**126**	**245**	**265**
1991	**316**	**130**	**242**	**268**
1992	**316**	**118**	**235**	**265**
1993	**299**	**121**	**227**	**253**
1994	**287**	**117**	**244**	**246**
1995	**283**	**113**	**285**	**248**
1996	**285**	**125**	**276**	**253**

Table 6: Emission intensities: Total Suspended Solids, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	**3713**	**9587**	**11726**	**6368**
1990	**3771**	**8405**	**14368**	**6091**
1991	**3502**	**8095**	**14973**	**6094**
1992	**3354**	**8407**	**13893**	**6216**
1993	**3314**	**8599**	**13786**	**6158**
1994	**3520**	**8969**	**13187**	**6131**
1995	**3488**	**8428**	**12976**	**5781**
1996	**3507**	**8765**	**13202**	**5792**

Table 7: Emission intensities: SO2, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	**1904**	**2871**	**3492**	**2389**
1990	**1977**	**2724**	**3817**	**2368**
1991	**1944**	**2762**	**3654**	**2356**
1992	**1915**	**2712**	**3498**	**2352**
1993	**1876**	**2758**	**3459**	**2322**
1994	**1884**	**2704**	**3538**	**2308**
1995	**1850**	**2558**	**3704**	**2244**
1996	**1853**	**2735**	**3678**	**2263**

Table 8: Emission intensities: NO2, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	**1142**	**1339**	**1726**	**1287**
1990	**1210**	**1327**	**1663**	**1292**
1991	**1195**	**1354**	**1576**	**1283**
1992	**1197**	**1352**	**1536**	**1288**
1993	**1163**	**1343**	**1515**	**1259**
1994	**1159**	**1300**	**1543**	**1247**
1995	**1131**	**1217**	**1616**	**1213**
1996	**1127**	**1304**	**1562**	**1218**

Table 9: Emission intensities: CO, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	**1743**	**2447**	**3152**	**2141**
1990	**1793**	**2280**	**3520**	**2114**
1991	**1757**	**2267**	**3520**	**2117**
1992	**1717**	**2285**	**3339**	**2118**
1993	**1685**	**2332**	**3329**	**2097**
1994	**1725**	**2344**	**3339**	**2102**
1995	**1671**	**2218**	**3388**	**2013**
1996	**1683**	**2347**	**3410**	**2037**

Table 10: Emission intensities: VOC, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	**835**	**788**	**1176**	**885**
1990	**875**	**788**	**1076**	**881**
1991	**868**	**799**	**996**	**873**
1992	**864**	**787**	**991**	**873**
1993	**854**	**792**	**981**	**865**
1994	**852**	**781**	**1008**	**862**
1995	**828**	**742**	**1032**	**837**
1996	**825**	**781**	**1002**	**840**

Table 11: Emission intensities: Fine particulates, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	**264**	**753**	**546**	**417**
1990	**268**	**723**	**610**	**408**
1991	**264**	**756**	**584**	**408**
1992	**266**	**763**	**568**	**414**
1993	**256**	**755**	**578**	**406**
1994	**257**	**707**	**565**	**396**
1995	**264**	**662**	**585**	**390**
1996	**261**	**717**	**584**	**391**

Table 12: Emission intensities: Total particulates, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	**514**	**880**	**844**	**649**
1990	**519**	**849**	**904**	**638**
1991	**518**	**885**	**836**	**637**
1992	**523**	**882**	**832**	**647**
1993	**504**	**877**	**842**	**634**
1994	**503**	**825**	**855**	**623**
1995	**506**	**775**	**928**	**618**
1996	**501**	**839**	**907**	**619**

Table 13: Emission intensities: Metals - land, kg/US$ millions, IPPS coefficients

Year	Consumption	Investment	Exports	Total
1985	**138**	**331**	**363**	**219**
1990	**140**	**292**	**465**	**213**
1991	**132**	**289**	**470**	**212**
1992	**124**	**284**	**438**	**211**
1993	**124**	**298**	**434**	**211**
1994	**129**	**305**	**431**	**212**
1995	**128**	**291**	**439**	**203**
1996	**129**	**306**	**453**	**206**

Despite the differences in the source of the coefficients from the previous exercise, the conclusions tend to be very similar: the emissions intensity of the export complex is always higher than the average emissions intensity of the economy and, in almost all cases, the highest emissions intensity is exactly the one of the export complex.

The average emissions intensity of the economy for all parameters has declined between 1985 and 1996 (with the exception of BOD, which has remained almost the same); nevertheless, the emissions intensities in the export complex have increased for all but two parameters (NO_2 and VOC).

The emissions intensities estimated according to the IPPS coefficients are considerably lower than the values obtained using the IPEA coefficients; this is a strong indication that the environmental profile of the Brazilian industry in the late 1980s was considerably worse than the US one.

These results are very consistent, showing a trend that exports are dependent on production chains that are potentially dirtier (according to the IPPS) than the average of the economy. Despite the methodological problems discussed previously, this is a strong indication of a composition effect in the direction of specialization in (potentially) contaminating industries.

IPEA-IE/UFRJ Emission Coefficients Inventory (Local Pollutants)

The third database used to estimate the emissions of local pollutants by Brazilian industry was built specifically for this study using data from CETESB (the environmental agency for the State of São Paulo). The calculation of industrial emissions generated in São Paulo was based on the information declared by local production units about their potential emissions and their capacity to abate them (obtaining, by residual, the level of remaining emissions) according to the CETESB inventory. Note that, again, these data do not refer to actual emissions, but to information given by the industries to the environmental agency (in that case, up to the end of 1996); therefore they also refer to “theoretical” (rather than observed) emissions.

These figures were then divided by the value of production (or value added, or employment) for every industrial sector in the State of São Paulo, in order to generate the emission coefficients. Ideally, the production data would have been obtained directly from the same local units surveyed by CETESB. However, since this comparison is impossible, the value of production of São Paulo industry, by sector, estimated by the Annual Industrial Survey (PIA/IBGE) for the year 1996 was used. Once the coefficients were estimated, they were applied to the industrial value of production for the country as a whole (assuming that the environmental performance of industries in São Paulo reflect the average behavior of Brazilian industry).

The emission coefficients obtained using these procedures were as follows: water pollutants (organic and inorganic); air pollutants (sulfur dioxide (SO_2) and particulates (total)). Table 14 presents the results using the emission coefficients estimated according to the CETESB inventory.

These results have important differences from the previous exercises. First, it is important to note that the emission coefficients are considerably smaller than the ones based on the IPEA data, but higher than those from IPPS. Considering the estimates for 1995, the average intensity for organic matter (equivalent to BOD) based on the IPEA-IE/UFRJ coefficients is 747 kg/US$ million, in contrast to 861 kg/US$ million estimated with the IPEA coefficients, and 248 kg/US$ million using the IPPS. The intensity for particulates obtained from the IPEA-IE/UFRJ coefficients is 2,608 kg/US$ million, while the same estimate using IPEA’s coefficients is 4,441 kg/US$ million and 618 kg/US$ million using the IPPS. The only exception is SO_2: the estimate of emission intensity based on the IPEA-IE/UFRJ coefficients (962 kg/US$ million) is smaller than the other two estimates (3,298 kg/US$ million using IPEA, and 2,244 kg/US$ million using IPPS). This may be evidence of the improvement in the environmental performance of the Brazilian industry during the 1990s, even though it still emits more than the US industry emitted a decade before (with the exception of SO_2).

Another important point is that the difference between the emission intensities of the export complex and the average of the economy is not as accentuated as in the previous cases. Indeed, the export complex intensity drops below the average intensity in some cases, particularly for SO_2. Nevertheless, in general terms, the conclusions are similar to the previous ones: the export complex tends to be more intensive in emissions than the rest of the economy (even though the difference from the other sectors is less accentuated).

Table 14: Emission Intensities, kg/US$ millions, IPEA-IE/UFRJ coefficients

Pollutant/year	Consumption	Investment	Exports	Total
Organic				
1985	**956**	**203**	**534**	**723**
1990	**937**	**203**	**590**	**736**

1991	**973**	**210**	**591**	**766**
1992	**972**	**199**	**623**	**764**
1993	**932**	**196**	**625**	**740**
1994	**925**	**184**	**647**	**732**
1995	**923**	**177**	**779**	**747**
1996	**903**	**190**	**744**	**744**
Inorganic				
1985	**7.7**	**7.6**	**8.8**	**7.9**
1990	**7.4**	**7.2**	**10.4**	**7.7**
1991	**6.9**	**7.2**	**10.5**	**7.5**
1992	**6.5**	**7.1**	**10.9**	**7.4**
1993	**6.8**	**7.4**	**11.4**	**7.7**
1994	**7.0**	**7.5**	**10.5**	**7.6**
1995	**6.8**	**7.3**	**10.5**	**7.4**
1996	**6.6**	**7.2**	**11.5**	**7.4**
Particulates				
1985	**2542**	**2839**	**2186**	**2542**
1990	**2378**	**2811**	**2384**	**2472**
1991	**2514**	**3019**	**2427**	**2601**
1992	**2617**	**3018**	**2470**	**2666**
1993	**2351**	**2974**	**2550**	**2503**
1994	**2445**	**2723**	**2843**	**2563**
1995	**2350**	**2549**	**3983**	**2608**
1996	**2388**	**2794**	**3667**	**2634**
SO_2				
1985	**928**	**1150**	**1026**	**992**

1990	**946**	**1158**	**943**	**991**
1991	**965**	**1232**	**894**	**1008**
1992	**977**	**1231**	**889**	**1009**
1993	**952**	**1220**	**890**	**991**
1994	**949**	**1129**	**919**	**981**
1995	**934**	**1058**	**945**	**962**
1996	**934**	**1151**	**939**	**976**

Carbon Dioxide Emissions from Fossil Fuel Consumption (Global Pollutant)

A recent study by COPPE/UFRJ (1998) estimated carbon dioxide (CO_2) emissions from fossil fuel consumption in Brazil during the period 1990/94. These data were obtained using the methodological procedures of the Intergovernmental Panel on Climate Change (IPCC) since they were used in the Brazilian official inventory of greenhouse gas emissions. Table 15 summarizes the main results.

Table 15: CO2 Emissions from Fossil Fuels Consumption, Brazil (1990/94)

Sector	1990		1991		1992		1993		1994	
	1000t CO_2	**%**	**1000t CO_2**	**%**	**1000t CO_2**	**%**	**1000t CO_2**	**%**	**1000t CO_2**	**%**
Energy	**13226.3**	**7.3**	**11875.2**	**6.3**	**12462.4**	**6.5**	**13471.4**	**6.7**	**13954.0**	**6.6**
Residential	**13767.5**	**7.6**	**14140.6**	**7.4**	**14650.2**	**7.6**	**15184.1**	**7.5**	**15188.4**	**7.2**
Commercial & Public	**2546.4**	**1.4**	**2428.0**	**1.3**	**2458.0**	**1.3**	**2411.6**	**1.2**	**3523.9**	**1.7**
Agriculture	**9997.8**	**5.5**	**10425.5**	**5.5**	**10726.2**	**5.6**	**11851.1**	**5.9**	**12516.4**	**5.9**
Industrial	**59850.3**	**33.2**	**65771.8**	**34.7**	**66635.1**	**34.6**	**69839.0**	**34.6**	**72272.2**	**34.3**
Transport	**81142.2**	**44.9**	**85165.7**	**44.9**	**85807.6**	**44.5**	**89214.8**	**44.2**	**93331.3**	**44.3**
Total	**180530.5**	**100.0**	**189806.9**	**100.0**	**192739.5**	**100.0**	**201972.1**	**100.0**	**210786.2**	**100.0**
Source: COPPE (1998)										

Using the same approach of the other exercises, based on equation (7), Table 16 presents the intensity coefficients (CO_2 per unit of output) in each production chain.

Table 16: Emission Intensity per Unit of Output (kg CO2/R$ 1994)

Year	Exports	Consumption*	Investment	Total	Annual change (%)
1990	**0.634**	**0.264**	**0.275**	**0.302**	
1991	**0.702**	**0.270**	**0.316**	**0.324**	**7.1%**
1992	**0.637**	**0.275**	**0.294**	**0.325**	**0.3%**
1993	**0.607**	**0.279**	**0.283**	**0.320**	**-1.5%**
1994	**0.635**	**0.281**	**0.303**	**0.326**	**1.,7%**
Change 94/90(%)	0.1%	6.7%	9.9%	7.8%	

The tables above clearly indicate that in every year considered, the relative contribution of the export complex to CO_2 emissions was always around twice the equivalent value of their contribution to total output. In other words, the production of export goods and their respective inputs is considerably more emission intensive than in the other chains. Even though the intensity of CO_2 per output unit remained relatively stable (while it increased in the rest of the economy), it remained almost as the double of the average intensity of the economy. This is additional strong evidence that the Brazilian economy has exported goods and services based on “dirty” activities.

In sector terms, again, most of the emissions are concentrated in a small number of 'dirty' activities, directly or indirectly related to exports: metallurgy, chemicals, agriculture (the high increase in agricultural emissions is a consequence of the mechanization process, resulting in more fuel consumption) and the transportation sector.

On the other hand, despite the accelerated growth in imported goods, the average emission intensity increased (more emissions required to produce the same amount of output). Therefore, the empirical evidence goes against the hypothesis that free trade and capital flows would lead to higher efficiency in environmental standards.

We conclude that despite all limitations (pollution estimates were not directly observed; the environmental impact of a specific pollutant is affected by many other variables which were not considered in the exercise; linear relationships between output and emissions may not be realistic; etc.) the results from these exercises are very consistent in showing the relatively high contribution of export-oriented activities to air and water pollution problems in Brazil. The convergence of these results with other empirical studies on the same issue (Veiga *et al.* 1995, Torres *et al.* 1997), but with a less aggregate perspective, is another strong element confirming the relative specialization in dirty industrial exports. Therefore, any expansion of export activities based on the existing set of parameters will lead to problems of increasing the level of industrial emissions more than a similar rise in domestic-oriented activities.

Nevertheless, it is crucial to note that only the composition effect was considered in these exercises. Most of the argument that more openness brings benefits to the environment is based on another aspect, the technological effect. This issue is discussed further in section 6.

6 Imports and Emission "Savings"

Estimating Emission Savings

An integrated analysis of the environmental impacts of international trade has to consider that liberalization may have an important impact on pollution because import goods reduce domestic levels of emissions. Since they are produced abroad, imports "divert" the associated emissions to the country where the good was made – the idea is that if no trade relations took place, they would have been produced domestically, increasing the level of emissions.

In this section, we examine the emission "savings" caused by the fast growth of industrial imports in Brazil after the trade liberalization policies took effect. These emission savings were estimated through the hypothetical increase in emissions if these import goods were made in Brazil. In methodological terms, this can be done using the same input-output and emission coefficient tables presented in the exercises in the previous section, but with a change – the table of the supply and demand of import goods was used (table 4 of the input-output matrix of IBGE), instead of the supply and demand tables of domestic products (table 3 of the input-output matrix). The emission coefficients were obtained from the aforementioned Industrial Pollution Projection System (IPPS) of the World Bank.

The flagship of the liberalization process was automobile imports, which increased 1,380% in the 1990-96 period. Other industrial sectors with very high rates of import growth where plastics (307%), textiles (286%), wood and furniture (248%), electronics (246%), other industries (220%), other metallurgic goods (200%), car components (200%), electrical equipment (199%) and vegetable oils (193%). The average increase in industrial imports was 148%, and the sectors with the lowest rates of import growth were slaughtering (-41%), sugar production (73%), footwear (78%) and chemical elements (88%).

Table 17 shows the aggregate emission savings for each pollutant in the 1990-1996 period. The average change in the associated level of (potential) emissions was 46%. At a first sight, this suggests a relative stability in the composition of imports in terms of emissions. However, one can observe that there were considerable differences among pollutants. In the case of metal emissions for water and BOD, for example, the growth in domestic emission savings was considerably below the average, showing that the composition of imports changed towards goods with low intensity in this water pollutant. On the other hand, the presence of import goods intensive in air pollutants (VOC, metals, SO_2, and NO_2) has increased in the same period, indicating that the emission savings effect have grown for these parameters.

Table 17: Emission savings (tons), IPPS coefficients, 1990-96

Pollutant	1990	1996	Change
BOD	**6,183.86**	**14,262.22**	**131%**
Total Suspended Solids	**175,387.86**	**429,782.33**	**145%**
SO_2	**65,818.26**	**167,426.61**	**154%**